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The use of fumaric acid derivatives for treating cardiac insufficiency, and asthma

The present invention relates to the use of fumaric acid derivatives for preparing a drug for treating cardiac insufficiency, and asthma.

Prior Art

Fumaric acid dialkyl esters and fumaric acid monoalkyl esters and salts thereof have been successfully used for treating psoriasis for a long time. The use has been described in a number of patents, cf. e.g. DE 25 30 372, DE 26 21 214 or EP-B-0 312 697.

Also, the use of fumaric acid mono- and diesters for treating autoimmune diseases such as e.g. polyarthritis or multiple sclerosis (cf. DE 197 21 099.6 and DE 198 53 487.6), but also for use in transplantation medicine (cf. DE 198 53 487.6 and DE 198 39 566.3) has been described. Moreover, the use of fumaric acid mono- and diesters for treating NFkappaB-mediated diseases as well as the treatment of mitochondrial diseases and/or as NFkappaB inhibitor is known from DE 101 01 307.8 and DE 100 00 577.2. All mentioned publications describe fumaric acid mono- and diesters, optionally in the form of certain salts.

Also, the use of fumaric acid mono- and diamides for treating said indications is known from DE 101 33 004.9. These amides are formed with amino acids and preferably with specific peptides. Finally, fumaric acid oligomers and their use for treating said diseases are known from DE 102 17 314.1.

A paroxysmal, marked respiratory distress is understood by asthma (bronchial asthma) from which approx. 4 to 5% of the population of the industrial nations are suffering, there being an upward tendency. This respiratory distress is based on a variable and reversible obstruction of the respiratory tract due to a hyperreactive bronchial system, which is trig-

gered by exogenic and/endogenic stimuli. These include chemical or physical provocative factors, infections, physical effort and/or emotional factors. After a longer duration of the disease, secondary diseases such as a chronic bronchitis, a pulmonary emphysema, bronchiectases, atelectases or a pulmonary heart disease or a respiratory cardiac insufficiency usually occur.

Depending upon the cause, differentiation is made between the following variants of asthma, namely asthma caused by allergies, infections, analgesics, job conditions or physical effort, mixed forms of asthma or asthma cardiale (cardiac asthma), nasal asthma and asthma uremicum. In particular, asthma cardiale may result in respiratory distress due to increased congestion in the lesser circulation in the case of a left ventricular insufficiency.

Nowadays, beta-2 sympathomimetics, corticosteroids, parasympatholytics, theophylline, anti-inflammatory agents and anti-allergic agents are, for instance, administered in the drug treatment of and/or for alleviating asthma, in addition to the still proven means of just avoiding the triggering stimulus.

On a molecular level, asthma seems to be characterized by an increased activity of Th2 lymphocytes in the lung, which, in turn, results in an increased release of some Th2 cytokines which, ultimately, gives rise to the known features of asthma such as IgE isotype switching, mucus production and recruitment and activation of eosinophils. Moreover, Th2 cytokines seem to result in the differentiation of further Th2 cells through the signal transduction pathway known as JAK-STAT, from which a self-enhancing circle results. An increased proliferation of mesenchymal cells, in particular bronchial smooth muscle cells, was also observed.

The so-called JAK-STAT signal transduction pathway (JAnus Kinase Signal Transducer and Activator of Transcription pathway) is a pathway for transmitting information to be transmitted by signal peptides such as e.g. cytokines to the interior of the cell and/or the nucleus. Signal transduction takes place through STAT proteins that are present in the cytoplasm and are at first inactive; 7 different STAT proteins are know in man. As a result of a receptor ligand bonding on the cell surface, these STAT proteins are quickly activated by

means of phosphorylation, e.g. by means of the Janus kinase. Phosphorylation results in the homo- or heterodimerization of the STAT proteins, the dimers being rapidly transported into the nucleus, where they bond to a target promoter and drastically enhance the transcription rate of this promoter.

An acute or chronic inability of the heart to deliver the output of blood required for metabolism and/or receive the venous return under stress (stress insufficiency) or already at rest (= rest insufficiency) are understood by cardiac insufficiency. The insufficiency may occur as a pure left ventricular or right ventricular insufficiency, but may as well affect both ventricles.

The clinical picture of cardiac insufficiency can be attributed to various causes in terms of etiology, above all to inflammatory and degenerative changes of the myocardium and endocardium, coronary circulatory disorders, myocardial infarction and injuries. Subsequently, cardiac insufficiency results in changes in the peripheral circulation, breathing disorders, in particular cardiac asthma, renal insufficiency and disorders of the electrolyte metabolism and edemas and a reduced functional capacity of the skeletal muscles.

As regards to the indication, differentiation is made between acute cardiac insufficiency, energetic cardiac insufficiency, energetic-dynamic cardiac insufficiency and hypodynamic cardiac insufficiency, also called HEGGLIN syndrome II, excitomotoric cardiac insufficiency, cardiac insufficiency as a result of cardiac arrythmics, hypoxemic, latent, primary, compensated, relative or stress insufficiency and/or left ventricular insufficiency.

At present, contraction-promoting substances are used for the drug treatment of cardiac insufficiency, glycosides (above all digoxin and digitoxin) being still used today for treating the chronic forms. However, during the last few years, vasodilators (nitro-compounds and dihydralazine, alpha blockers, calcium antagonists and above all ACE inhibitors) have gained in importance. ACE inhibitors are most important for long-term treatment. Moreover, diuretics are used. Acute forms are treated with catecholamines, possibly also with amrinone.

It is an object of the invention to provide a further agent for the treatment of cardiac insufficiency and asthma. In particular, it is an object of the invention to provide a therapeutic agent for both cardiac asthma and left ventricular insufficiency in the area in which they overlap with each other. It is another object of the invention to provide a therapeutic agent for both indications individually or in the area in which they overlap with each other, which, due to its good tolerance, is suited for long-term therapy.

The present object is attained by the use of fumaric acid derivatives for preparing pharmaceuticals or pharmaceutical preparations for treating asthma and/or cardiac insufficiency, in particular in man.

Summary of the invention

According to a first aspect the invention relates to the use of fumaric acid derivatives selected from the group consisting of dialkyl fumarates, monoalkyl hydrogen fumarates, fumaric acid monoalkyl ester salts, fumaric acid monoamides, monoamido fumaric acid salts, fumaric acid diamides, monoalkyl monoamido fumarates, carbocyclic and oxacarbocyclic oligomers of these compounds and mixtures thereof for preparing a pharmaceutical preparation for the treatment or prevention of cardiac insufficiency, in particular left ventricular insufficiency, myocardial infarction and angina pectoris.

According to a second aspect the invention relates to the use of fumaric acid derivatives, selected from the group consisting of dialkyl fumarates, monoalkyl hydrogen fumarates, fumaric acid monoalkyl ester salts, fumaric acid monoamides, monoamido fumaric acid salts, fumaric acid diamides, monoalkyl monoamido fumarates, carbocyclic and oxacarbocyclic oligomers of these compounds and mixtures thereof for preparing a pharmaceutical prepration for the treatment of asthma and chronic obstructive pulmonary diseases, especially asthma caused by allergies, infections, analgesics, job conditions or physical effort, mixed forms of asthma, or asthma cardiale.

The present invention likewise concerns a method for inhibiting ^{3}H-thymidine uptake by bronchial smooth muscle cells, and a method of inhibiting proliferation of these cells as described below and in the appending claims.

The present invention finally concerns the use of the above fumaric acid derivatives for inhibiting the PDGF induced STAT1 activation.

Description of the drawings

Fig. 1 is a bar chart which shows the extent of infarctions after administration of DMF, ischemia and for controls.

Fig. 2 shows the percentage inhibition of PDGF-induced ^{3}H-thymidine incorporation in bronchial smooth muscle cells, when DMF is added.

Fig. 3 is a bar chart showing percentage of cell proliferation of bronchial smooth muscle cells upon PDGF stimulation in the absence or presence of DMF and/or dexamethasone.

Fig. 4 is a bar chart showing left ventricular enddiastolic diameters on Dahl rats before and after 8 weeks of high salt diet in the absence and presence of DMF.

Detailed description of the invention

According to one aspect thereof the present invention relates to the use of fumaric acid derivatives for preparing a pharmaceutical preparation for treating asthma and chronic obstructive pulmonary diseases in general. Preferably, this asthma is caused by allergies, infections, analgesics, job conditions or physical effort, particularly preferred asthma cardiale.

According to a second aspect thereof the invention also relates to the use of fumaric acid derivatives for preparing a pharmaceutical preparation for treating or preventing cardiac insufficiency, myocardial infarction and angina pectoris. The cardiac insufficiency con-

cerned may be any type of cardiac insufficiency regardless of its form and/or etiology. Examples of cardiac insufficiency to be treated according to the invention are acute cardiac insufficiency, energetic cardiac insufficiency, energetic-dynamic cardiac insufficiency and hypodynamic cardiac insufficiency, also called HEGGLIN syndrome II, excitomotor cardiac insufficiency, cardiac insufficiency as a result of cardiac irregularities, hypoxemic, latent, primary, compensated, decompensated, relative or stress insufficiency and/or left ventricular insufficiency most preferably, left ventricular insufficiency. The compositions are also effective in preventing these illnesses and/or myocordial infarctions, including first, second or further infarctions.

These uses are based on the finding that fumaric acid derivatives inhibit PDGF- (platelet derived growth factor) induced STAT1 activation. As described above, it was assumed that, in asthma, STAT activation results in a shifting of the cytokine pattern and, ultimately, in a vicious circle with increased Th2 cell activity and the consequences of mucous secretion, IgE production and recruiting of eosinophils (A.B. Pernis, P.B. Rothman, "JAK-STAT signalling in asthma" in: The J. of Clin. Investigation, vol. 10, No. 1, May 2002).

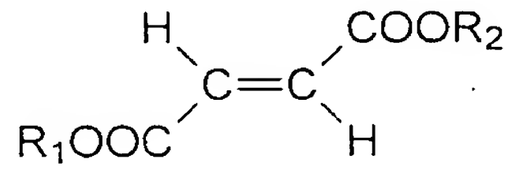
The shifting of the cytokine pattern from Th1 to Th2 that is described in the literature for the substance class of fumaric acid derivatives (cf. the aforementioned patent specifications) would rather give rise to expecting an intensification of this vicious circle. Accordingly, they would not be suited for treating asthma. Surprisingly, it turned out that fumaric acid derivatives can inhibit the proliferation of smooth muscle cells of the respiratory tract. This seems to take place through the inhibition of the PDGF-inducible transcription factor STAT1. It was possible to specifically show that fumaric acid derivatives can inhibit the PDGF-induced STAT1 activation and the PDGF-stimulated thymidine incorporation in BSM (bronchial smooth muscle) cells. Without wanting to be bound thereby, this proliferation-inhibiting effect could be causal for both the effectiveness of fumaric acid derivatives in the therapy of asthma.

The fumaric acid derivatives to be used according to the invention may be one or several selected from the group consisting of dialkyl fumarates (fumaric acid dialkyl esters, respectively), monoalkyl hydrogen fumarates (fumaric acid monoalkyl esters, respectively),

monoalkyl ester fumaric acid salts (fumaric acid monoalkyl ester salts, respectively) of physiologically acceptable cations, in particular alkaline or alkaline earth metal cations or transition metal cations such as Li^+, Na^+, K^+, NH_4^+, Mg^{2+}, Ca^{2+}, Fe^{2+}, Mn^{2+}, and Zn^{2+}, fumaric acid monoamides and fumaric acid diamides and their salts, carbocyclic and oxacarbocyclic oligomers of these compounds and mixtures thereof.

In a preferred embodiment the fumaric acid derivative is selected from the group consisting of optionally substituted fumaric acid dialkyl esters and fumaric acid monoalkyl esters in the form of the free acid or its salts and mixtures thereof.

Particularly prefered in this case is the use of fumaric acid dialkyl esters of the formula (I)



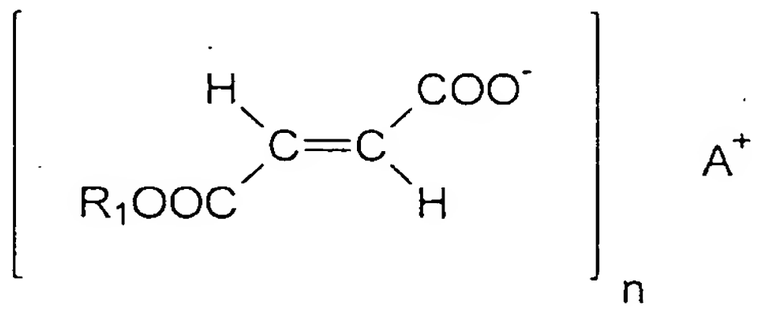
as they are described in DE 198 53 487.6, wherein R_1 and R_2 which may be the same or different independently represent a C_{1-24} alkyl radical or a C_{5-20} aryl radical and these radicals are optionally substituted with halogen (F, Cl, Br, I), hydroxy, C_{1-4} alkoxy, nitro or cyano. With special preference, the dialkyl fumarate is dimethyl fumarate, diethyl fumarate and/or methyl ethyl fumarate.

In general, an alkyl group is to be understood as a saturated or unsaturated, straight-chain, branched or cyclic hydrocarbon group having 1 to 24 carbon atoms according to the invention, which may be optionally substituted with one or more substituents. Preferably, the alkyl group is methyl, ethyl, n-propyl, isopropyl, n-butyl, sec-butyl, t-butyl, pentyl, cyclopentyl, 2-ethylhexyl, hexyl, cyclohexyl, heptyl, cycloheptyl, octyl, vinyl, allyl, 2-hydroxy ethyl, 2- hydroxy propyl, 3-hydroxy propyl, 2,3-dihydroxypropyl, 2-methoxy ethyl, methoxy methyl, 2-methoxy propyl, 3-methoxy propyl or 2,3-dimethoxy propyl. Methyl or ethyl are most preferred.

According to the invention an aryl group is to be understood as an optionally substituted aryl, alkyl substituted aryl or aralkyl group having 5 to 20 carbon atoms, preferably an aryl, alkyl substituted aryl or aralkyl group having 6 to 10 carbon atoms. Exemplary groups are phenyl, benzyl, phenethyl, methyl phenyl, ethyl phenyl, propyl phenyl and butyl phenyl, t-butyl phenyl, phenyl and benzyl being especially preferred.

The substituents of said groups are preferably selected from the group consisting of halogen (F, Cl, Br, I), hydroxy, C_{1-4} alkoxy, C_{1-4} alkyl, nitro and cyano.

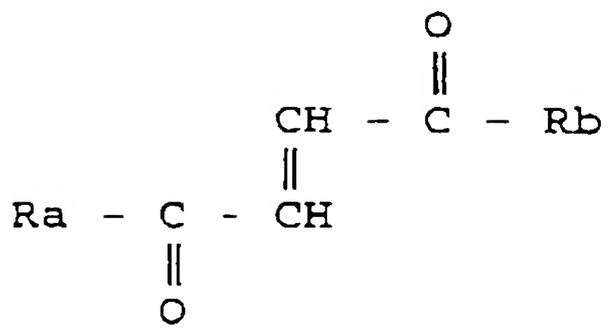
Fumaric acid monoalkyl esters of the formula (II)



as they are described in DE 197 21 099.6 can also be advantageously used, wherein R_1 is as defined above, A is hydrogen, an alkaline or alkaline earth metal cation or a physiologically acceptable transition metal cation, preferably selected from Li^+, Na^+, K^+, Mg^{2+}, Ca^{2+}, Zn^{2+}, Fe^{2+}, and Mn^{2+}, and n equals 1 or 2 and corresponds to the valence of A.

Exemplary compounds of the formulae (I) and (II) are fumaric acid dimethyl ester, fumaric acid diethyl ester, fumaric acid methyl ethyl ester, methyl hydrogen fumarate, ethyl hydrogen fumarate, calcium methyl fumarate, calcium ethyl fumarate, magnesium methyl fumarate, magnesium ethyl fumarate, zinc methyl fumarate, zinc ethyl fumarate, iron methyl fumarate and iron ethyl fumarate. They can be used individually or as mixtures.

Preferably, the fumaric acid amides to be used according to the invention are those described in DE 101 33 004.9. They correspond to the general formula (III)



(III)

wherein

R_a represents OR_3 or a D- or L-amino acid radical -NH-CHR_4-COOH bonded via an amide bond, wherein R_3 is hydrogen, a straight-chain or branched, optionally substituted C_{1-24} alkyl radical, a phenyl radical or a C_{6-10} aryl or aralkyl radical and R_4 is a side chain of a natural or synthetic amino acid; and

R_b represents a D- or L-amino acid radical -NH-CHR_5-COOH bonded via an amide bond, wherein R_5 is a side chain of a natural or synthetic amino acid, or a peptide radical with 2 to 100 amino acids bonded via an amide bond, wherein each amino acid may be the same or different.

The side chain of a natural or synthetic amino acid is typically a side chain selected from the group consisting of the side chains of Ala, Val, Leu, Ile, Trp, Phe, Met, Tyr, Thr, Cys, Asn, Gln, Asp, Glu, Lys, Arg, His, Citrulline, Hcy, Hse, Hyp, Hyl, Orn, Sar, and Me-Gly. The side chains of Gly, Ala, Val, Ile, Leu, and Me-Gly are preferred. If R_a is an L amino acid radical -NH-CHR_4-COOH and R_b is an L-amino acid radical -NH-CHR_5-COOH, R_4 and R_5 may be the same or different. More preferably, R_4 and R_5 are the same. Most preferably R_a and R_b each are glycine.

Alternatively, R_a may be the radical -OR_3, and R_b may be an L-amino acid radical -NH-CHR_5-COOH or a peptide radical, R_5 having the meaning indicated above. In this case, the fumaric acid derivative is a monoalkyl monoamido fumarate.

The peptide radical is bonded via an amide bond and has 2 to 100, preferably 2 to 30, most preferably 2 to 15 amino acids, which may be the same or different. The peptide radical R_b

is most preferably selected from the group consisting of peptide hormones, growth factors, cytokines, neurotransmitters, neuropeptides, antibody fragments, coagulation factors and cyclosporines and derivatives and fragments thereof. Preferably, R_a is methoxy or ethoxy and R_b is Gly, Ala, Val, Ile, Leu and Me-Gly.

The fumaric acid amides as defined above can be used individually or in admixture or also in mixture with the fumaric acid monoalkyl or dialkyl esters defined above.

Finally, carbocyclic or oxacarbocyclic fumaric acid oligomers can also be used as they are described in DE 102 17 314.1. They contain 2 to 10, preferably 2 to 6 and most preferably 2 to 3 units derived from fumaric acid and/or its esters and/or amides as defined above as repetitive units.

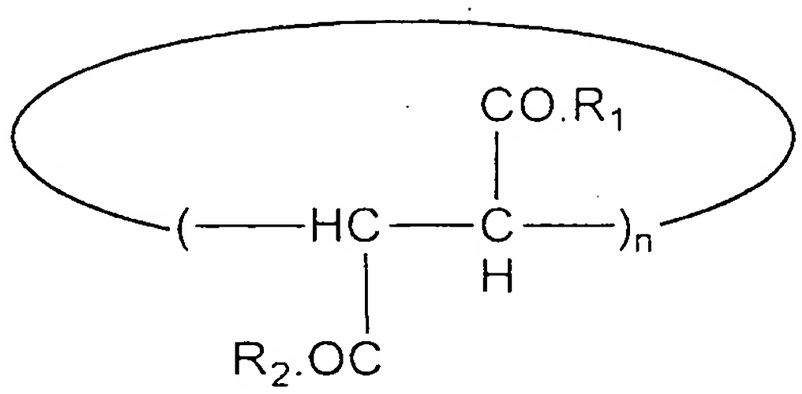
These fumaric acid oligomers are preferably obtained by means of the (olefinic) polymerization of the C-C double bonds (for the carbocyclic oligomers) and/or the C-C double bonds and the carbonyl oxygens of the units (for the oxacarbocyclic oligomers). Preferably, the units derived from the fumaric acid are derived from monomers selected from the group consisting of fumaric acid and the dialkyl fumarates, monoalkyl hydrogen fumarates, fumaric acid monoamides, fumaric acid diamides, monoalkyl monoamido fumarates and their salts and mixtures thereof, which are defined above. More preferably, the oligomer only contains units derived from one or two monomers. Most preferably, the oligomer exclusively contains identical monomer units.

The carbocyclic oligomers are composed of the units derived from the fumaric acid in such a way that the units are bonded to the carbon atoms 2 and 3 of the fumaric acid backbone by means of covalent C-C bonds in such a way that a carbocyclic oligomer is formed. The oligomer backbone comprises an even number of carbon atoms and does not contain any other monomers and/or heteroatoms. This backbone is substituted at each carbon atom with one of the carboxylic acid and/or carboxylic acid amide groups of the fumaric acid monomer unit(s), from which it is built up.

The oxacarboxylic oligomers are composed of the fumaric acid monomers in such a way that the units are bonded to each other at the carbon atoms 1 and 3 via ether bridges. At the same time, the ethylenic unsaturation of the atoms C_2 and C_3 is shifted to C_1 and C_2. Thus, the ring contains polyoxypropene units in the case of the oxacarboxyclic oligomers according to the invention.

The term "oligomer" used herein relates to a number of at least two fumaric acid monomer units. Customarily, the carboxyclic fumaric acid oligomer contains 2 to 10, preferably 2 to 6 and most preferably 2 to 3 units derived from fumaric acid. Preferably, the carboxylic acid and/or carboxylic acid amide groups as substituents of the cycle are all in a trans-position to each other.

In a preferred embodiment, a carbocyclic fumaric acid oligomer corresponding to the following formula (IVa)

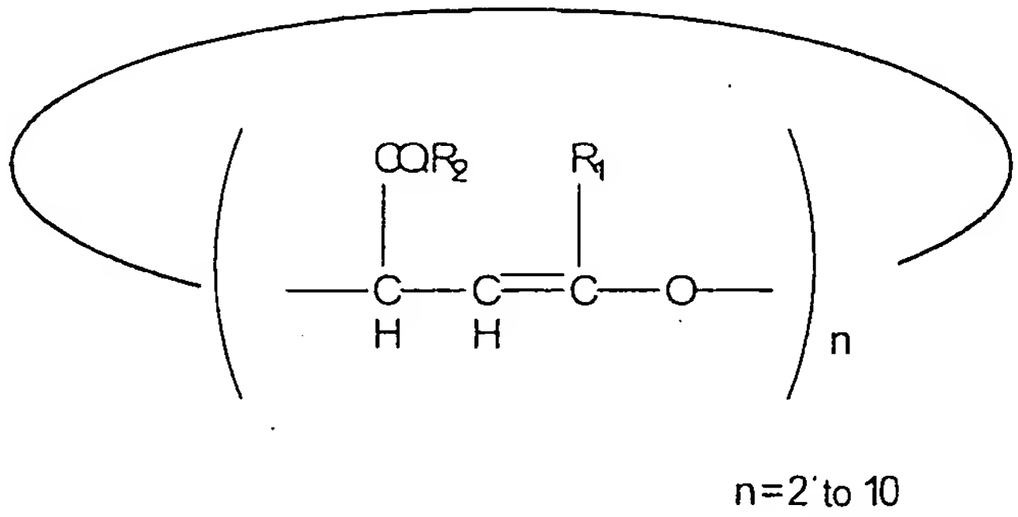


is used, wherein the radicals R_c and R_d are the same or different and are selected among amine radicals ($-NR_1R_2$), amino acid radicals -NH-C(COOH)-R_5, peptide radicals having 2 to 100 amino acids, alkoxy radicals ($-OR_1$) and a hydroxyl radical, R_1, R_2 and R_5 being as defined above and n being an integer from 2 to 10 inclusive, preferably 2 to 6 inclusive.

Preferably, the radicals R_c and R_d each are independently an alkoxyl or hydroxyl radical, R_c and R_d not meaning hydroxyl at the same time with the greatest preference. Thus, the monomer(s) is (are) preferably one or several monoalkyl hydrogen fumarate(s). In another embodiment both radicals R_c and R_d may represent an alkoxy radical $-OR_1$ which, still more preferred, is identical. In this case, the monomer(s) is (are) dialkyl fumarates.

Very preferably, the r-1,t-2,c-3,t-4- tetrakis(methoxy carbonyl) cyclobutane or the r-1,t-2,c-3,t-4,c-5,t-6-hexa(alkoxy carbonyl) cyclohexane, preferably the r-1,t-2,c-3,t-4-tetrakis(methoxy carbonyl) cyclobutane and/or the r-1,t-2,c-3,t-4c-5,t-6-hexa(methoxy carbonyl) cyclohexane is used according to this embodiment.

Alternatively, the oxacarbocylic oligomer of the formula (IVb):



n=2 to 10

is used, wherein R_1 and R_2 are as defined above and n is an integer from 2 to 10 inclusive, more preferably 2 to 6 inclusive.

The fumaric acid derivatives to be used according to the invention can be prepared according to known processes as they are e.g. described in DE 197 21 099.6, DE 101 33 004.9 or DE 102 17 314.1. The content of these publications is incorporated herein by reference.

The pharmaceutical preparation may be present in a form suitable for oral, rectal, transdermal, dermal, ophthalmological, nasal, pulmonary or parenteral application. Preferably, the pharmaceutical preparation is suited for oral administration. It may then be present in the form of tablets, coated tablets, capsules, granulate, solutions for drinking, liposomes, nano-particles, nano-capsules, micro-capsules, micro-tablets, pellets or powders and in the form of granulate filled in capsules or sachets, micro-tablets filled in capsules or sachets, pellets filled in capsules or sachets, nano-particles filled in capsules or sachets or powder filled in capsules or sachets. Preferably, the drug is present in the form of nano-particles, pellets or micro-tablets, which may optionally be filled in sachets or capsules.

Preferably, all solid oral dosage forms may be provided with an enteric coating. It may e.g. be applied onto the tablets, micro-tablets, pellets, etc., but may also be applied onto the capsules that contain them.

The oral pharmaceutical forms according to the invention may basically be prepared according to the classic compaction method and also by direct compaction and as solid dispersions according to the melting method or by means of the spray drying method. If desired, an enteric coating can be poured or sprayed in portions onto the tablet cores in a classic coating pan or applied by means of a fluidized-bed apparatus according to known processes. Subsequently, after drying has been completed, a film coat can be applied in the same apparatus.

Preferably, the fumaric acid derivatives for preparing the pharmaceutical preparations according to the invention are used in such an amount that this pharmaceutical preparation contains an amount of one or more fumaric acid derivative(s) per dosage unit which corresponds and/or is equivalent to an amount of 1 to 500 mg, preferably 10 to 300 mg, and mostly preferred 10 to 200 mg fumaric acid.

In the case of an parenteral administration via an injection (iv, im, sc, ip) the preparation is present in a form suitable for this. All customary liquid carriers suitable for the injection can be used.

According to a preferred embodiment the drug to be produced according to the invention can contain the following individually or in admixture: 10 to 500 mg dialkyl fumarate, in particular dimethyl fumarate and/or diethyl fumarate, 10 to 500 mg calcium alkyl fumarate, in particular calcium methyl fumarate and/or calcium ethyl fumarate, 0 to 250 mg zinc alkyl fumarate, in particular zinc methyl fumarate and/or zinc ethyl fumarate, 0 to 250 mg alkyl hydrogen fumarate, in particular methyl hydrogen fumarate and/or ethyl hydrogen fumarate and 0 to 250 mg magnesium alkyl fumarate, in particular magnesium methyl fumarate and/or magnesium ethyl fumarate, the sum of said amounts corresponding to an

equivalent of 1 to 500 mg, preferably 10 to 300 mg and most preferred 10 to 200 mg fumaric acid.

Preparations according to the invention that are used with special preference contain exclusively dimethyl fumarate in an amount of 10 to 300 mg.

According to an especially preferred embodiment the pharmaceutical preparation is present in the form of micro-tablets or pellets. They have preferably a size and/or a mean diameter of ≤ 5000 micrometers, preferably 300 to 2500 micrometers, in particular 300 to 1000 micrometers for pellets and 1000 to 2500 micrometers for micro-tablets. Due to the administration of the fumaric acid derivatives in the form of micro-tablets, which is preferred according to the invention, gastrointestinal irritations and/or side effects which cannot be excluded in the administration of conventional single unit dose tablets can be further reduced. Presumably, this is based on the fact that the micro-tablets, preferably enteric coated micro-tablets, already are already distributed in the stomach and thus get into the intestine boluswise, where the active substances are released in locally smaller doses with the entire dosage being the same. Due to this, the local irritation of the epithelial cells of the intestine can be avoided, the better gastrointestinal tolerance of the micro-tablets as compared with conventional tablets resulting from this.

Examples of preparation

To explain the use according to the invention, various examples for the preparation of preferred pharmaceutical preparations are given below. The examples are for illustrations purposes only, but not to restrict the invention.

Example 1

Preparation of film tablets with an enteric coating containing 100.0 mg of monomethyl fumarate-Ca salt, which corresponds to 78 mg of fumaric acid

Taking the necessary precautions (breathing mask, gloves, protective clothing, etc.), 10 kg of monomethyl fumarate-Ca salt are crushed, mixed intensely and homogenized by means

of a sieve 800. Then an excipient mixture of the following composition is prepared: 21 kg of starch derivative (STA-RX 1500®), 2 kg of micro-crystalline cellulose (Avicel PH 101®), 0.6 kg of polyvinyl pyrrolidone (PVP, Kollidon® 25), 4 kg of Primogel®, 0.3 kg of colloidal silicic acid (Aerosil®).

The active ingredient is added to the entire powder mixture, mixed, homogenized by means of a sieve 200 and processed with a 2% aqueous solution of polyvinyl pyrrolidone (PVP, Kollidon® 25) in the usual manner into binder granules, and then mixed with the outer phase in a dry state. The latter consists of 2 kg of a so-called FST complex containing 80% of talcum, 10% of silicic acid and 10% of magnesium stearate.

Thereafter, the mixture is pressed into convex tablets with a weight of 400 mg and a diameter of 10.0 mm by the usual method. Instead of these classic compaction methods, other methods such as direct compaction or solid dispersions according to the melting method and the spray drying method may also be used for preparing tablets.

Enteric coating:

A solution of 2.250 kg of hydroxy propyl methyl cellulose phthalate (HPMCP, Pharmacoat HP® 50) is dissolved in a solvent mixture consisting of 2.50 l of demineralized water, 13 l of acetone Ph. Helv. VII and 13 l of ethanol (94% by weight) and then 0.240 kg of castor oil (Ph. Eur. II) is added to the solution. The solution is poured or sprayed in portions onto the tablet cores in a coating pan in a conventional manner.

After a corresponding drying, the film coating is subsequently applied. Said coating consists of a solution of Eudragit® E 12.5% 4.8 kg, talcum Ph. Eur. II 0.34 kg, titanium(VI) oxide Cronus RN 56® 0.52 kg, coloured lacquer ZLT-2 blue (Siegle) 0.21 kg, and polyethylene glycol 6000 Ph. Helv. VII 0.12 kg in a solvent mixture of 8.2 kg of 2-propanol Ph. Helv. VII, 0.06 kg of glycerine triacetate (Triacetin®) and 0.2 kg of demineralized water. Homogenous distribution in the coating pan or the fluidized bed, is followed by drying and polishing in the usual manner.

Example 2

Preparation of enteric coated capsules containing 86.5 mg of monoethyl fumarate-Ca salt and 110.0 mg of dimethyl fumarate, which corresponds to a total of 150 mg of fumaric acid

Taking the necessary precautions (breathing mask, gloves, protective clothing, etc.), 8.65 kg of monoethyl fumarate-Ca salt and 11 kg of dimethyl fumarate are intensely mixed with a mixture consisting of 15 kg of starch, 6 kg of lactose Ph. Helv. VII, 2 kg of micro-crystalline cellulose (Avicel®), 1 kg of polyvinyl pyrrolidone (Kollidon® 25) and 4 kg of Primogel® and homogenized by means of a sieve 800.

Together with a 2% aqueous solution of polyvinyl pyrrolidone (Kollidon® 25) the entire powder mixture is processed in the usual manner into a binder granulate and mixed with the outer phase in the dried state. Said outer phase consists of 0.35 kg of colloidal silicic acid (Aerosil®), 0.5 kg of magnesium stearate and 1.5 kg of talcum Ph. Helv. VII. The homogeneous mixture is then filled in portions of 500.0 mg into appropriate capsules which are then provided with an enteric (gastric-acid resistant) coating consisting of hydroxy propyl ethyl cellulose phthalate and castor oil as softening agent in a customary fashion.

Example 3

Preparation of enteric micro-tablets in capsules containing 87.0 mg of monoethyl fumarate-Ca salt, 120 mg of dimethyl fumarate, 5.0 mg of monoethyl fumarate-Mg salt and 3.0 mg of monoethyl fumarate-Zn salt, which corresponds to a total of 164 mg of fumaric acid ("*forte*" tablets)

Taking the necessary precautions (breathing mask, gloves, protective clothing, etc.), 8.7 kg of monoethyl fumarate-Ca salt, 12 kg of dimethyl fumarate, 0.5 kg of monoethyl fumarate-Mg salt and 0.3 kg of monoethyl fumarate-Zn salt are crushed, intensely mixed and homogenized by means of an sieve 800. An excipient mixture of the following composition is prepared: 18 kg of starch derivative (STA-RX 1500), 0.3 kg of micro-crystalline cellulose (Avicel PH 101), 0.75 kg of PVP (Kollidon 120), 4 kg of Primogel, 0.25 kg of colloidal

silicic acid (Aerosil). The entire powder mixture is added to the active ingredient mixture, homogenized by means of a 200 sieve, and processed in the usual manner with a 2% aqueous solution of polyvinyl pyrrolidone (Kollidon K25) to obtain a binder granulate and mixed in a dry state with the outer phase that consists of 0.5 kg of magnesium stearate and 1.5 kg of talcum. Then the powder mixture is pressed by the conventional method into convex micro-tablets with a gross mass of 10.0 mg and a diameter of 2.0 mm.

The enteric (gastric acid-resistant) coating is applied in a fluidized-bed apparatus. In order to achieve resistance to gastric acid, portions of a solution of 2.250 kg of hydroxy propyl methyl cellulose phthalate (HPMCP, Pharmacoat HP 50) are dissolved in a mixture of the following solvents: acetone 13 l, ethanol 94% by weight denatured with 2% ketone 13.5 l and demineralized water 2.5 l. 0.240 kg of castor oil are added as softening agent to the finished solution and applied in portions onto the tablet cores in the usual manner.

Film coat: After drying is completed, a suspension of the following composition is then applied as a film coat in the same apparatus: talcum 0.340 kg, titanium(VI) oxide Cronus RN 56 0.4 kg, coloured lacquer L red lacquer 86837 0.324 kg, Eudragit E 12.5% 4.8 kg and polyethylene glycol 6000 pH 11 XI 0.12 kg in a solvent mixture of the following composition: 2-propanol 8.17 kg, demineralized water 0.2 kg and glycerine triacetate (Triacetin) 0.6 kg.

The gastric acid-resistant micro-tablets are analyzed with respect to their ingredients and are then filled into hard gelatine capsules at a corresponding net weight and sealed.

Example 4

Preparation of enteric micro-tablets in capsules containing 120.0 mg dimethyl fumarate which corresponds to 96 mg fumaric acid

Taking the necessary precautions (breathing mask, gloves, protective clothing, etc.) 12 kg of dimethyl fumarate are crushed and homogenized by means of a 800 sieve. An excipient mixture of the following composition is prepared: 17.5 kg of starch derivative (STA-RX®

1500), 0.30 kg of micro-crystalline cellulose (Avicel® PH 101), 0.75 kg of PVP (Kollidon® 120), 4 kg of Primogel®, 0.25 kg of colloidal silicic acid (Aerosil®). The entire powder mixture is added to the active ingredient mixture, mixed, homogenized by means of a 200 sieve, processed in the usual manner with a 2% aqueous solution of polyvinyl pyrrolidone (Kollidon® K25) to obtain a binder granulate and mixed in a dry state with the outer phase which consists of 0.5 kg of Mg stearate and 1.5 kg of talcum.

Then, the powder mixture is pressed by the conventional method into convex micro-tablets with a gross mass of 10.0 mg and a diameter of 2.0 mm.

To achieve resistance to gastric acid, portions of a solution of 2.25 kg hydroxy propyl methyl cellulose phthalate (HPMCP, Pharmacoat® HP 50) are e.g. dissolved in a mixture of the following solvents: acetone 13 l, ethanol (94% by weight denatured with 2% ketone) 13.5 l and demineralized water 1.5 l. Castor oil (0.24 kg) is added as softening agent to the finished solution and applied in portions onto the tablet cores in the usual manner.

After drying is completed, a suspension of the following composition is then applied as a film coat in the same apparatus: talcum 0.34 kg, titanium(VI) oxide Cronus RN 56 0.4 kg, coloured lacquer L red lacquer 86837 0.324 kg, Eudragit E 12.5% 4.8 kg and polyethylene glycol 6000 pH 11 XI 0.12 kg in a solvent mixture of the following composition: 2-propanol 8.17 kg, demineralized water 0.2 kg and glycerine triacetate (Triacetin) 0.6 kg.

The gastric acid-resistant micro-tablets are analyzed with respect to their ingredients and are then filled into hard gelatine capsules at a corresponding net weight and sealed.

Example 5

Preparation of enteric micro-tablets in capsules containing 120.0 mg of diglycine fumaric acid diamide, which corresponds to 96 mg of fumaric acid

12 kg of diglycine fumaric acid diamide are crushed and homogenized as indicated above. An excipient mixture of the following composition is prepared: 23.2 kg of micro-crystalline cellulose (Avicel® PH 200), 3 kg of croscarmelose sodium (AC-Di-SOL-SD-

711), 2.5 kg of talcum, 0.1 kg of anhydrous silicic acid (Aerosil® 200) and 1 kg Mg stearate. The entire powder mixture is added to the active ingredient mixture and homogeneously mixed. Then, the powder mixture is pressed by the direct compaction into convex micro-tablets with a gross mass of 10.0 mg and a diameter of 2.0 mm.

Subsequently, a solution of 0.94 Eudragit® in isopropanol is prepared which, additionally, contains 0.07 kg dibutyl phthalate. This solution is sprayed onto the tablet cores. Then, a dispersion of 17.32 kg Eudragit® L D-55 and a mixture of 2.8 kg micro-talcum, 2 kg Macrogol 6000 and 0.07 kg Dimeticon in water is prepared and sprayed onto the cores.

Subsequently, the enteric micro-tablets are analyzed with respect to their ingredients and filled into hard gelatine capsules at a corresponding net weight and sealed.

Example 6

Preparation of enteric micro-tablets in capsules containing 60.0 mg of r-1,t-2,c-3,t-4-tetrakis(methoxy carbonyl) cyclobutane and 30.0 mg r-1,t-2,c-3,t-4,c-5,t-6-hexa(methoxy carbonyl) cyclohexane

60 kg of r-1,t-2,c-1,t-4-tetrakis(methoxy carbonyl) cyclobutane and 3.0 kg of r-1,t-2,c-3,t-4,c-5,t-6-hexa(methoxy carbonyl) cyclohexane are crushed, intensely mixed and homogenized by means of sieve 800. An excipient mixture of the following composition is prepared: 18 kg of starch derivative (STA-RX 1500®), 0.30 kg of micro-crystalline cellulose (Avicel PH 101), 0.75 kg of PVP (Kollidon 120), 4.00 kg of Primogel, 0.25 kg of colloidal silicic acid (Aerosil). The active ingredient is added to the entire powder mixture and homogenized by means of a sieve 200 and processed with a 2% aqueous solution of polyvinyl pyrrolidone (Kollidon K25) in the usual manner into binder granules, and then mixed with the outer phase in a dry state. The latter consists of 0.50 kg of Mg stearate and 1.50 kg of talcum. Thereafter, the powder mixture is pressed into convex micro-tablets with a gross mass of 10.0 mg and a diameter of 2.0 mm by the usual method.

The enteric (gastric acid-resistant) coating is poured onto the tablet cores in a classic coating pan. In order to achieve resistance to gastric acid, portions of a solution of 2.250 kg of

hydroxy propyl methyl cellulose phthalate (HPMCP, Pharmacoat HP 50) are dissolved in a mixture of the following solvents: acetone 13.00 l, ethanol 94% by weight denatured with 2% ketone 13.50 l and demineralized water 2.50 l. 0.240 kg of castor oil is added as softening agent to the finished solution and applied in portions to the tablet cores in the usual manner.

Film coat: After drying is completed, a suspension of the following composition is applied as a film coat in the same apparatus: talcum 0.340 kg, titanium(VI) oxide Cronus RN 56 0.400 kg, coloured lacquer L red lacquer 86837 0.324 kg, Eudragit E 12.5% 4.800 kg and polyethylene glycol 6000 pH 11 XI 0.120 kg in a solvent mixture of the following composition: 2-propanol 8.170 kg, demineralized water 0.200 kg and glycerine triacetate (Triacetin) 0.600 kg.

Subsequently, the enteric micro-tablets are analyzed with respect to their active ingredients and filled into hard gelatine capsules at a corresponding net weight and sealed.

Example 7

Preparation of a suspension for parenteral application 60.0 mg of r-1,t-2,c-4,t-4-tetrakis(methoxy carbonyl) cyclobutane and 30.0 mg r-1,t-2,c-3,t-4,c-5,t-6-hexa(methoxy carbonyl) cyclohexane

Ingredients	mg/ml
r-1,t-2,c-3,t-4-tetrakis(methoxy carbonyl) cyclobutane	60.00
r-1,t-2,c-3,t-4,c-5,t-6-hexa(methoxy carbonyl) cyclohexane	30.00
Methyl cellulose	0.25
Sodium citrate, dihydrate	30.00
Benzyl alcohol	9.00
Methyl p-hydroxybenzoic acid	1.80
Propyl p-hydroxybenzoic acid	1.20
Water for injection purposes	q.s.a.d. 1.00

The aforementioned ingredients are processed to a parenteral suspension using standard techniques.

Examples of application

Example A

In vivo data on the treatment of cardiac insufficiency with DMF using a rat model.

The effects of dimethyl fumarate were examined in the present experiment using the model of acute ischemia and reperfusion of the rat. For this purpose, healthy, male rats were divided into three groups with 17 animals each. In the tests, an ischemia was caused for 45 minutes through an occlusion of an artery with the heart being exposed and, subsequently, reperfusion was carried out for 120 minutes. Finally, a myocardial infarction was triggered by means of a reocclusion and the risk area was determined by means of dyeing with phthalocyanine blue.

The administration of the test substance was carried out iv at the beginning of the first occlusion. The control group received 0.02% DMSO (0.5 ml/kg body weight), the DMF group received 10 mg dimethyl fumarate in 0.02% DMSO (0.5 ml/kg body weight). The animals were ischemically preconditioned in the second group (2 times 5 minutes each ischemia and reperfusion).

The results are represented in Fig. 1. Evidently, both dimethyl fumarate (DMF) and the ischemic preconditioning (IPC) limited the size of the infarction to a statistically significant degree in our experiments, the risk area being similar in all 3 groups. Thus, the data proves that the used dimethyl fumarate can significantly reduce the size of the infarction and thus prevent a cardiac insufficiency.

Example B

Inhibition of the PDGF-induced incorporation of thymidine

The successful treatment of asthma involves three different pathways: (1) the reduced release of inflammatory mediators in allergic responses, (2) the inhibition of T-lymphocyte invasion, and (3) the inhibition of mesenchymal cell proliferation. Glucocorticoids, which are the treatment of choice in asthma, have been shown to inhibit mesenchymal cell proliferation. This test can thus be used to screen for possible other active substances for treatment of asthma.

BSM (bronchial smooth muscle) cells were cultivated in RPMI, 0.3% albumin and 0.1% DMSO at 37°C in the presence of 0, 1, 5, 10 and 20 ng/ml on PDGF with and without 10^{-5} M dimethyl fumarate.

After a predetermined period of time, 5μCi on ^{3}H-thymidine was added to the culture medium and incubation was continued for further 24 hours. The incorporation was finally stopped by means of centrifugation, removal of the supernatant, washing and lysis of the cells. The incorporation on ^{3}H-thymidine was measured by determining the radioactivity in the lysates in a liquid scintillation device in comparison to the control. The results are shown in Fig. 2 as percentage values as compared with the control (100%). The addition of PDGF evidently increases the ^{3}H-thymidine incorporation and, thus, cell proliferation, whereas this increase is significantly reduced upon addition of dimethyl fumarate.

Example C

Bronchial smooth muscle cells were grown in 96 well plates until they reached 60-70 % confluency. The cells were then starved for 48 h in serum free, 0.3 % albumine containing RPMI medium. One hour before stimulation of cell proliferation with 10 ng/ml PDGF, the cells were treated with with (a) 10^{-5} M DMF, (b) 10^{-8} M dexamethasone (dexa), or (c) 10^{-5} M DMF and 10^{-8} M dexa. As a controll untreated cells (buffer only) were used. Cells were treated for 36 h, whereafter 4μCi of ^{3}H-thymidine was added for further 8 hours. The cells were lysed, DNA-incorporated ^{3}H-thymidine bound to filter membranes, and the incorporated cpm measured in a liquid scintillation device. The results are shown in Fig. 3 in percentage of control (100 %) and compared to PDGF induced proliferation.

When treating cells with dexa alone (10^{-8} M), which is a therapeutically relevant dosage, cell proliferation was reduced to about 116 ± 11 %. A comparable reduction was seen with DMF at 10^{-5} M (117 ± 4 %). Combined administration of DMF and dexa in these concentrations resulted in a synergistic decrease of cell proliferation to nearly baseline levels (95 ± 11 %). These results show that DMF may be useful in the treatment of asthma, either as of its own, and also in combination with dexametasone or glucocorticoids in general.

In a specifically preferred embodiment for the treatment of asthma and chronically obstructive lung diseases such treatment is thus in combination with a glucocorticoid. Administration can be in the same dosage unit or in separate dosage units. Administration can also be in parallel or sequentially. Preferably the glucocorticoid is selected from the group consisting of dexamethasone, cortisone, hydrocortisone, prednisolone, prednisone, methylprednisolone, fluocortolone, triamcinolone, betamethasone, beclomethasone, budenoside, flunisonide, fluticasone, and pharmaceutically acceptable salts and derivatives thereof. Most preferably the glucocorticoid is dexamethasone.

Example D

Dahl-rats, which are salt sensitive, were administered varying dosages of DMF on a daily basis and put on a high salt diet. After 8 weeks of treatment the left ventricular enddiastolic diameters were measured for test and control groups by echocardiographic analysis. Groups measured were control (0 mg DMF; n = 9); group 1 (2 x 5 mg DMF / kg/d; n = 9) and group 2 (2 x 15 mg DMF / kg/d; n = 11).

In the echocardiography analysis, DMF prevented the dilatation of the left ventricle after 8 weeks of high salt diet in dose dependent manner. Specifically, in the DMF groups the inner diameter of the left ventricle remained in the same range as at baseline (see Fig. 4). In contrast, animals in the control group showed an enlarged left ventricle indicating dilatation of the left ventricle. Importantly, dilatation of the left ventricle marks the transition from compensated hypertrophy to decompensated heart failure. Consequently, DMF delays the transition to heart failure, and thus prevents myocardial infarctions.